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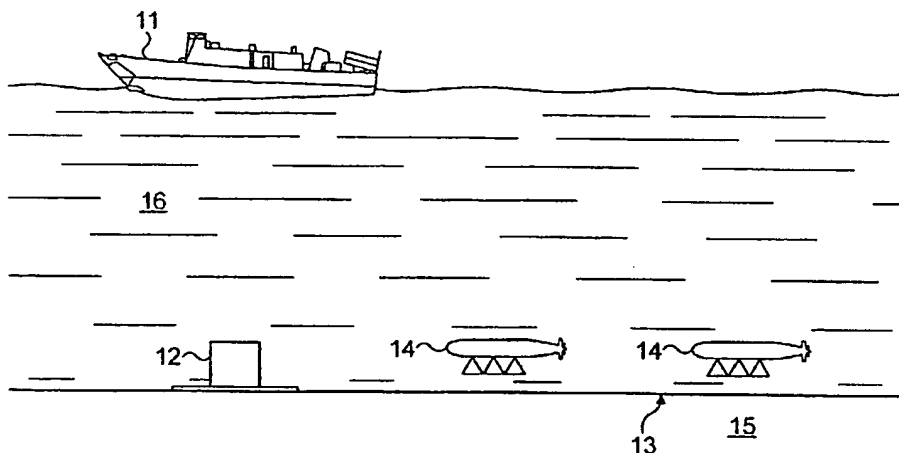
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(54) Title: SEISMIC EXPLORATION



(57) Abstract: The present invention provides a seismic exploration and imaging system for producing seismic survey reports of subsea geological structures. The exploration system provides a method in which both P-waves and S-waves are detected without the need for placing detection apparatus in contact the seabed. A seismic event is applied (12) to the earth's surface (13), and the detected response including P-waves and S-waves in the earth's. The detecting apparatus comprises a means for monitoring and recording the response to the seismic event in the form of movements of particles at the earth's surface, from a position spaced from the earth's surface. Particles at the surface will respond both to P-wave and S-wave stimulation and so their movements will be representative of the two waves. These movements are detected from a distance.

WO 2004/003589 A1

Seismic Exploration

The present invention relates to seismic exploration techniques and the seismic imaging of subsurface layers. It is particularly but not exclusively concerned with submarine seismic exploration and with producing seismic survey reports of subsea geological structures.

Conventional seismic methods for exploring subterranean strata beneath the seabed involve generating a seismic wave and measuring the response. The seismic wave may be simple or complex and may be generated at sea level, beneath the surface of the water or at the seabed. The response is detected by a series of spaced receivers which are commonly positioned on cables towed behind an exploration vessel. Generally, the receivers are held stationary for the detection step and are then moved to a different location and the process is repeated.

The response to a seismic event in the solid rock at the sea floor includes a compression wave (P-wave) and a shear wave (S-wave). P-waves are considered well suited to imaging structures while the combination of S-waves is well suited to determining rock and fluid characteristics. P-waves travel through rock and sea water while S-waves travel through rock only. Thus, if the receivers are hydrophones floating at or beneath the surface, they will detect only the P-waves. In order to detect the S-waves, it is necessary to use geophones located at the seabed.

It has also been recognised that better seismic imaging can be achieved by making use of both P- and S-waves. However, the costs involved in positioning and re-positioning geophones on the sea bed in addition to the use of hydrophones has been found to be prohibitively costly. This is particularly

so since in order to detect S-waves effectively, three independent orthogonal geophones are required at each recording location.

Specifically, it has been known for more than 10 years that 4C seismic imaging
5 of the subsurface may add more and better information to exploration due to high quality recording of shear waves (S-waves) at the water bottom.

Unfortunately, 4C-imaging did not become the success that was expected, primarily due to the combination of extreme high acquisition cost and uncertainties in the prediction of payback. The cost factor is related to capacity
10 problems in available acquisition techniques.

4C recording is normally carried out by a hydrophone and three independent orthogonal geophones. The geophones are coupled to the sea bottom and they are therefore sensitive to the particle velocities generated by both the seismic p-
15 waves and the s-waves. These techniques use either sensor cables at the sea bottom or geophone nodes resting on or planted in the sea bottom. 4C seismic acquisition consists of a sequence of moving source and moving receiver operations. After an independent source vessel has carried out a series of shooting profiles, the bottom equipment has to be moved into the next position.
20 Both due to this static recording component in the acquisition and due to a limited number of available receivers, these 4C acquisition systems become ineffective. Due to physical problems both related to moving the heavy equipment along the water bottom and geophone coupling, the reliability is adversely affected.

25 Finally, it is also recognised that the cost effectiveness of carrying out such seismic imaging, and in particular S-wave measurements, could be greatly reduced by avoiding the need to locate detection apparatus at the seabed, that is to measure an S-wave from a position spaced from the seabed and so allow

effective re-positioning of the detection apparatus with respect to the seabed. However, as mentioned, S-waves do not travel through sea water, making direct sensing remote from the seabed impossible. Remote sensing has further inherent problems in that the detection apparatus is subjected to ocean currents
5 which can inhibit effective positioning of the detection apparatus, and introduce noise into measurements, making correlation of the results very difficult.

It is therefore an object of the invention to provide a method of seismic
10 exploration in which both P-waves and S-waves are detected but which is simpler and less costly than known techniques.

According to one aspect of the invention, there is provided a method of seismic exploration which comprises: generating a seismic event; applying the seismic
15 event to the earth's surface; detecting a response to the event, the detected response including P-waves and S-waves in the earth's surface; and analysing the detected response; and in which: the detecting step comprises monitoring and recording the response to the seismic event in the form of movements of particles at the earth's surface, from a position spaced from the earth's surface,
20 the detecting step being carried out over a response period, the response period being a predetermined period of time after the seismic event; and the analysing step comprises analysing the movements of particles at the earth's surface in the recorded response to the seismic event during the response period.

25 According to another aspect of the invention, there is provided apparatus for carrying out seismic exploration which comprises: means for generating a seismic event; means for applying the seismic event to the earth's surface; detecting apparatus for detecting a response to the event including P-waves and S-waves in the earth's surface; and means for analysing the detected response;

and in which: the detecting apparatus comprises monitoring apparatus and recording apparatus arranged to monitor and record the response to the seismic event in the form of movements of particles at the earth's surface, from a position spaced from the earth's surface, over a predetermined response period
5 after the seismic event. The invention also extends to a method for the production of a seismic survey report, using the method and/or apparatus set out above, and also to a report produced in this way.

The particles at the surface will respond both to P-wave and S-wave
10 stimulation and so their movements will be representative of the two waves. Since these movements are detected from a distance, the disadvantages of the prior art are avoided with there being no need to make contact with the surface and therefore no need to disengage before repositioning the detecting apparatus.

15 Preferably, the movements of the particles are monitored using light, in the form of visible light, x-rays, UV light or IR light, or using another form of radiation including radio waves, radar, sonar or using acoustic waves, in positioning principles from photogrammetry including interference
20 measurements and acoustic positioning. The monitoring apparatus may be kept stationary during the response period and is then moved to a different position after the response period, and the method is then repeated. Alternatively, it may be moved relative to the earth's surface during the response period; the analysing step then preferably includes the elimination from the detected
25 response of noise caused by the relative movement of the monitoring apparatus.

The monitoring apparatus preferably comprises several monitoring devices which are used simultaneously at different locations. Preferably, the response is transformed to and recorded in digital form. Preferably, the analysing step

comprises analysing surface particle displacements and/or velocities and/or accelerations by measurements of changes in the distance (velocity) between a monitoring device such as a camera and the surface and the camera velocity. The camera velocity can be measured separately by three camera mounted
5 accelerometers.

The z-component of the surface particle velocity is similar to the pressure component which will be measured with a mounted hydrophone on the monitoring device. This redundant measurement can be used to calibrate the
10 system and make it more robust against ambient noise and system noise.

In a preferred embodiment, the monitoring apparatus comprises three sources of coherent mono frequency light directed at the surface area being monitored, and a receiver for the reflected coherent light beam. Preferably, the coherent
15 light and a reference light beam are used to make speckle patterns by means of interferometry, and by monitoring the time variation in light intensity within a subset of speckles, the 3D-particle velocity in the surface can be calculated using interferometry principles.

20 With such measurements, the spatially and temporally coherent reference beam is scattered from the seabed and the seabed being a diffuse surface, produces a specular reflection. This specular reflection scattered from the seabed is the contribution of many scattered wavelets which have a constant relative phase determined by the optical path-length from each point on the seabed.

25 Combining the reflected light with the coherent reference beam creates a complex interference pattern as a result of the difference in optical path length in reflections from the surface. An initial imaging processing step, where the interference pattern is subtracted from a known reference image, reveals the temporal progression of the 3-D particle displacement as a result of the seismic

event. Furthermore, the signal to noise ratio may be improved by choosing multiple reference images to reduce speckle decorrelation effects. A final image processing step produces absolute intensity signal of the change in optical path as a result of said 3-D particle displacement. Finally, the intensity
5 signal is then subjected to signal processing steps which recover the seismic S-wave signals in question.

Due to the relative movement between surface and the "camera", the speckle pattern seen by the light detector may change within the seismic time. When
10 the camera is moving, the speckle pattern moves very fast and therefore the speckle monitoring must be carried out much more often than every 1ms to be able to detect/recognise and therefore monitor the same speckle group every ms.

15 Due to the seismic wavelengths, the particle velocity may be in phase within a 5m disc on the surface. Therefore groups of spatial distributed cameras can be used to increase signal to noise ratio in one seismic recording channel.

In one embodiment the monitoring apparatus comprises video recording
20 apparatus. The video recording apparatus may include one or more cameras operating on the basis of visible light. By detecting the changing positions of selected surface objects in pictures taken with several cameras, the 3D-particle velocity can be calculated using standard photogrammetry principles.

25 Due to slower variation in these full field wave field measurements than in the speckle pattern picture, the time sampling rate can be lower, more in the order of the seismic time sampling (ms).

The invention is particularly suitable for marine seismics, in which the earth's surface is the sea bed, the seismic event is applied to the sea or directly to the sea bed and the monitoring apparatus is spaced above the sea bed. Preferably, the monitoring apparatus is located from 1 to 15 metres above the sea floor
5 during the response period. The detecting apparatus may additionally include a hydrophone to record P-waves separately.

The detecting apparatus may be towed, eg. as a streamer or series of streamers behind a surface or submarine vessel. Thus, the detecting apparatus preferably
10 comprises a plurality of monitoring devices mounted on a plurality of cables, the monitoring devices on each cable preferably being spaced from each other by a distance which is less than the wavelength of the transmitted seismic event to prevent spatial aliasing of the recorded wavefield. Alternatively, it may be located on a self-propelled submarine vessel. In such an arrangement, the
15 vessel is preferably unmanned and would preferably include an rf transmitter/receiver and aerial, an acoustic modem, an acoustic housing sensor, a bottom sensor, a depth sensor and an acoustic tracking system, in addition to the monitoring apparatus. In either case, the analysing step should include the elimination from the detected response of noise representing disturbances
20 caused by the motion of the detecting apparatus. This motion can be measured by three independent accelerometers and diameters and then subtracted from the relative motion measured by the camera.

Preferably, the particles whose movements are detected are sand particles on
25 the sea floor.

Preferably, the seismic event comprises a seismic wave having a wavelength in the range 5 to 100m and a duration from 2 ms to 1000ms. Depending upon the depth of the exploration target and the seismic P and S-velocities, preferably,

the response period is from 5 to 20 seconds. The seismic event may be generated using apparatus on a surface vessel. It may be generated at the surface or below the surface of the ocean. The event may be generated at the sea bed by seismic sources using the land seismic source principles, in which case P and S-waves can be generated.

The recording apparatus may be combined with the monitoring apparatus in a way similar to a video camera with a tape or other recording medium, but having three channels for stereo mapping and image analysis to recognize, detect and position image objects. Alternatively, the monitoring apparatus, eg. a camera, may have its output transmitted to a remote recording device, which may be on a surface vessel.

The detecting device is preferably moving during the transmission period at a speed in the range 1 to 5 m/s, more preferably 3 to 4 m/s. The sampling rate is preferably 1 to 2ms. Thus, in the case of a camera, a picture would have to be made more often than the seismic sampling (ms) ie. $\ll 1$ ms eg. $1 \mu\text{s}$ to 0.1ms and the effective number of pictures/second > 100 .

From each picture from the cameras a 3D velocity is extracted.

Clearly, since such a camera or an Ocean Bottom Movie Recorder (OBM) is moving in the water while recording, an unwanted dynamic component is added to the movie (towing noise). Parts of this noise can be separated from the recording by standard temporal and spatial filters. The noise which falls inside the frequency band of the particle velocity has to be calculated/predicted before it can be removed. The prediction of towing noise can be achieved using hydrophone measurements from single hydrophones attached to the

camera, since these are proportional to the vertical particle velocity of the sea bottom detected, and by three accelerometers attached to the camera.

5 The relative movement in the OBM vessels/cables can also be partly
predicted/eliminated by processing data from several recorders which at the
same time, but from different places on the vessel/cable more or less record the
same part of the wavefront. This can be achieved with a camera separation less
than a wavelength of the seismic wave. If the resolution in the recording is
good enough, relative positioning of the recorders can be derived by image
10 analysis and the towing noise can be predicted as a result.

The OBM's may be towed in a similar geometry as the marine multi-streamer
spread used for pure P-wave seismic acquisition, but at a depth as close as
possible to the sea bottom.

15 The invention may be carried into practice in various ways and some
embodiments will now be described with reference to the accompanying
drawings, in which:

20 Figure 1 is a schematic diagram of the overall system; and

Figures 2, 3 and 4 are schematic plan views of three different data acquisition
schemes.

25 Referring to Figure 1, the operation is controlled by a surface vessel 11. A
seismic source 12 is located on the seabed 13 and a series of mobile camera
units 14 (of which two are shown) monitor the response at the seabed 13 to a
seismic wave generated by the source 12. The camera units 14 are positioned
about a metre above the seabed 13.

The camera units 14 each include a light transmitter, a receiver, a hydrophone, an accelerometer and a processing unit. The transmitter transmits light in the form of expanding rays, concentrated rays, modulated light and/or three
5 independent rays. The receiver may comprise a full field array, a coupled array or a single detector.

The hydrophone is present to measure seismic P-waves above the sea bottom 13. The accelerometer measures camera oscillations in the 0-200 Hz range.
10 The processing unit serves to filter noise (camera oscillations) from the measurements taken, to recognise and detect image objects, to measure image object values and convert those values to particle velocities.

In use, the source 12 generates a seismic wave with a response which lasts for a
15 period of 5 to 20 seconds which propagates through the bedrock 15 as P- and S-waves. The initial seismic wave is reflected and/or refracted at various stratum boundaries and the returning P- and S-waves cause oscillations in the up to 200 Hz range at the sea bottom 13 whose surface includes mud, sand and rocks. The camera units 14 monitor the response at the sea bottom 13 by
20 applying light to the bottom 13 and recording the reflected light (ie. the cameras 14 film the bottom 13) at a sampling rate of 0.000001 to 4 ms but generally <1ms. In effect, this constitutes a movie of the particles on the sea bottom 13 as they move in response to the returning P- and S-waves.

25 The returning P-wave also progresses from the seabed 13 up through the water 16 and is detected by the hydrophone, at a sampling rate of 1 to 4 ms and this data is conveyed to the processing unit. The accelerometer conveys noise data corresponding to camera oscillations to the processing unit.

The processing unit analyses the data collected from the receiver, the hydrophone and the accelerometer and produces a record of the response of the sea bottom particles, compensated for movement of the camera. This record can then be analysed using standard principles for seismic processing interpretation and characterisation of structures, stratigraphic features and rock and fluid parameters.

Thus for each seismic shot from the source 12, all camera units 14 simultaneously record the wavefield response at the sea bottom 13 in 2 to 4 ms movie samples. The camera units 14 carry out a preprocessing step which includes noise reduction, resolution enhancement, and image object identification. The camera unit dynamics are calculated and removed from the movies. Then V_x , V_y and V_z (the three velocity components of the S-wave) and P (the pressure from the P-wave) are derived and stored on four seismic traces. This is repeated each 2 to 4 ms.

In an alternative embodiment, the seismic source is not at a fixed location on the seabed, but is in fact a moving P-wave source which may for example be located on the vessel 11. The P-wave generated travels through the water 16 and into the bedrock 15 where it propagates and is reflected/refracted as P- and S-waves as before.

Figure 2 shows an arrangement in which the seismic source 21 is moving, and which includes an array of camera units 22 which is moving and also a seismic receiver 23 which is moving. Four cameras are shown in each array though there could be a greater number. An ideal arrangement would include 1 to 3 sources at a spacing of 50 to 400 m. The seismic receiver 23 is spaced from the sources also by a distance of 25 to 400 m and records for 5 to 20 seconds (depending on the transmission period) at a sampling rate of 1 to 4 ms. The

camera units 22 and seismic receiver 23 move at a speed of 1 to 5 ms. The bottom source is fixed while the floating, towed source is moving. The seismic receiver is the centre where all measurements are stored, where the steering is controlled, where energy can be distributed from, and where the operators are housed. This is similar to a seismic vessel which tows a seismic source and receivers today, and which would record/store the seismic information.

Figure 3 shows an alternative arrangement in which the sources 31, optimally 1 to 3 in number, are moveable at a speed of 1 to 5 ms, while the camera units 32 and seismic receivers 33 are fixed. The spacings are similar to those in the previous arrangement.

Figure 4 shows a third arrangement, corresponding to Figure 1, in which the sources 41 (again optimally 1 to 3 in number) are fixed, while the camera units 42 and the seismic receiver 43 are moveable. The spacings and speeds are as for the first arrangement.

The camera units would normally be mounted on or connected to cables which are towed behind a vessel or by a dedicated submarine propulsion device. The position of the cameras relative to the seabed is determined by acoustic techniques and the cables are steered by "wings" on the cables. Vertical forces on the cables are balanced by weights or ballast. The cables provide mechanical connection between an array of camera units and also provide energy and communication convections. In a typical arrangement there are several cables, each towing an array of camera units.

The vessel or towing device includes navigation equipment and data storage, through the camera units also have data storage.

13

Alternatively, the connection between the camera units may be wireless eg. a radio connection either instead of or in addition to the cables.

5

Claims

1. A method of seismic exploration which comprises: generating a seismic event; applying the seismic event to the earth's surface (13); detecting a
5 response to the event, the detected response including P-waves and S-waves in the earth's surface (13); and analysing the detected response; and in which: the detecting step comprises monitoring and recording the response to the seismic event in the form of movements of particles at the earth's surface (13), from a position spaced from the earth's surface (13), the detecting step being carried
10 out over a response period, the response period being a predetermined period of time after the seismic event; and the analysing step comprises analysing the movements of particles at the earth's surface (13) in the recorded response to the seismic event during the response period.
- 15 2. A method as claimed in Claim 1, in which the movements of the particles are monitored using light, in the form of visible light, x-rays, UV light or IR light, or using another form of radiation including radio waves, radar, sonar or using acoustic waves.
- 20 3. A method as claimed in Claim 1 or Claim 2, in which the monitoring is carried out using monitoring apparatus (14) which is moved relative to the earth's surface (13) during the response period.
- 25 4. A method as claimed in Claim 3, in which the analysing step includes the elimination from the detected response of noise caused by the relative movement of the monitoring apparatus.
5. A method as claimed in Claim 1 or Claim 2, in which the monitoring is carried out using monitoring apparatus (32) which is kept stationary during the

response period and is then moved to a different position after the response period, and the method is then repeated.

- 5 6. A method as claimed in any of Claims 3 to 5, in which the monitoring apparatus comprises several monitoring devices (14) which are used simultaneously at different locations.
- 10 7. A method as claimed in any preceding Claim, in which the response is transformed to and recorded in digital form.
8. A method as claimed in any preceding Claim, in which the analysing step comprises analysing surface particle displacements and/or velocities and/or accelerations.
- 15 9. A method as claimed in any of Claims 2 to 8, in which the monitoring apparatus comprises three sources of coherent mono frequency light directed at the surface area being monitored, and a receiver for reflected coherent light, or a single source of coherent light and three receivers.
- 20 10. A method as claimed in Claim 9, in which the coherent light and a reference beam are used to make speckle patterns by means of interferometry, and changes in the speckle patterns are analysed in the analysing step.
- 25 11. A method as claimed in any of Claims 2 to 8, in which the monitoring apparatus (14) comprises video recording apparatus.
12. A method as claimed in Claim 11, in which the video recording apparatus includes one or more cameras operating on the basis of visible light.

16

13. A method of marine seismic exploration, as claimed in any preceding Claim, and in which the earth's surface is the sea bed (13), the seismic event is applied to the sea or directly to the sea bed and the monitoring apparatus (14) is spaced above the sea bed.

5

14. A method as claimed in Claim 13, in which the monitoring apparatus is located from 0.5 to 5 metres above the sea floor during the response period.

10

15. A method as claimed in Claim 13 or Claim 14, in which the monitoring apparatus (14) additionally comprises a hydrophone.

15

16. A method as claimed in any of Claims 13 to 15, in which the monitoring apparatus is either towed or is self-propelled and the analysing step includes the elimination from the detected response of noise representing disturbances caused by the motion of the monitoring apparatus.

20

17. A method as claimed in any of Claims 13 to 16, in which the particles whose movements are detected are sand particles on the sea floor (13).

18. A method as claimed in any of Claims 13 to 17 in which the seismic event comprises a seismic wave having a wavelength in the range 5 to 100 m and a duration of up to 3s.

25

19. A method as claimed in any of Claims 13 to 18 in which the response period is from 4 to 8 seconds.

20. A method as claimed in any of Claims 13 to 19, in which the monitoring apparatus comprises a plurality of monitoring devices (22) mounted on a plurality of cables, the monitoring devices on each cable being spaced from

each other by a distance which is less than the wavelength of the transmitted seismic event.

21. Apparatus for carrying out seismic exploration which comprises: means
5 for generating a seismic event (12); means for applying the seismic event to the earth's surface; detecting apparatus (14) for detecting a response to the event including P-waves and S-waves in the earth's surface (13); and means for analysing the detected response; and in which: the detecting apparatus (14) comprises monitoring apparatus and recording apparatus arranged to monitor
10 and record the response to the seismic event in the form of movements of particles at the earth's surface (13), from a position spaced from the earth's surface (13), over a predetermined response period after the seismic event.

22. Apparatus as claimed in Claim 21, in which the monitoring apparatus
15 (14) uses light, in the form of visible light, x-rays, UV light or iv light or uses another form of radiation including radio waves, radar, sonar or uses acoustic waves.

23. Apparatus as claimed in any of Claims 21 to Claim 23, in which the
20 monitoring apparatus (14) is movable relative to the earth's surface during the response period.

24. Apparatus as claimed in Claim 21 or Claim 22, in which the monitoring
apparatus (14) is capable of being kept stationary during the response period
25 and then moved to a different position after the response period.

25. Apparatus as claimed in any of Claims 21 to Claim 24, in which the monitoring apparatus comprises several monitoring devices (22) which are used simultaneously at different locations.

26. Apparatus as claimed in any of Claims 21 to 25, in which the monitoring apparatus (14) comprises three sources of coherent light arranged to be directed at the area being monitored, and a receiver for reflected coherent light.

5

27. Apparatus as claimed in any of Claims 21 to 25, in which the monitoring apparatus (14) comprises video recording apparatus and the recorded response is a visual record.

10 28. Apparatus for marine seismic exploration, as claimed in any of Claims 21 to 27, and in which: the earth's surface is the sea bed (13), the seismic event is arranged to be applied to the sea or directly to the sea bed and the monitoring apparatus (14) is arranged to be spaced above the sea bed (13).

15 29. Apparatus as claimed in Claim 28, in which the detecting apparatus additionally comprises a hydrophone.

30. Apparatus as claimed in Claim 28 or Claim 29, in which the detecting apparatus is either arranged to be towed by a vessel or is self-propelled.

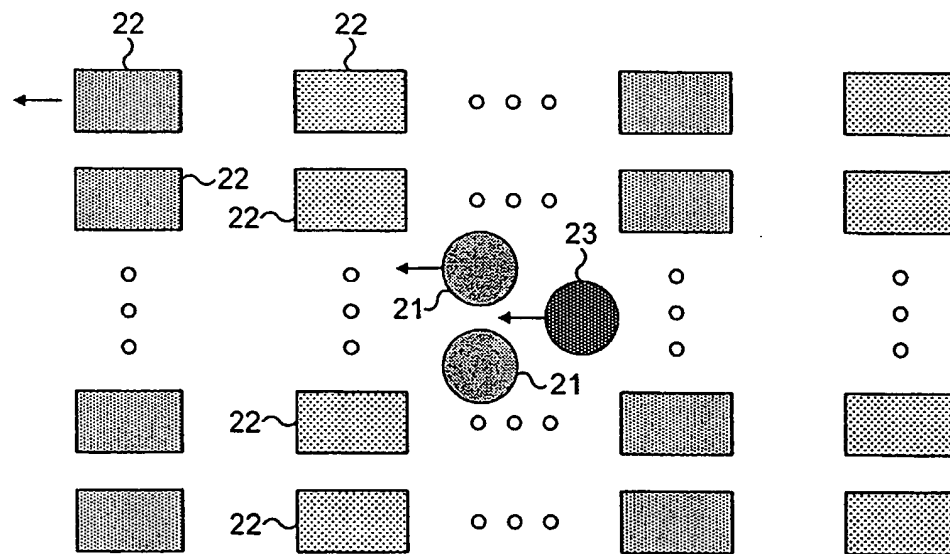
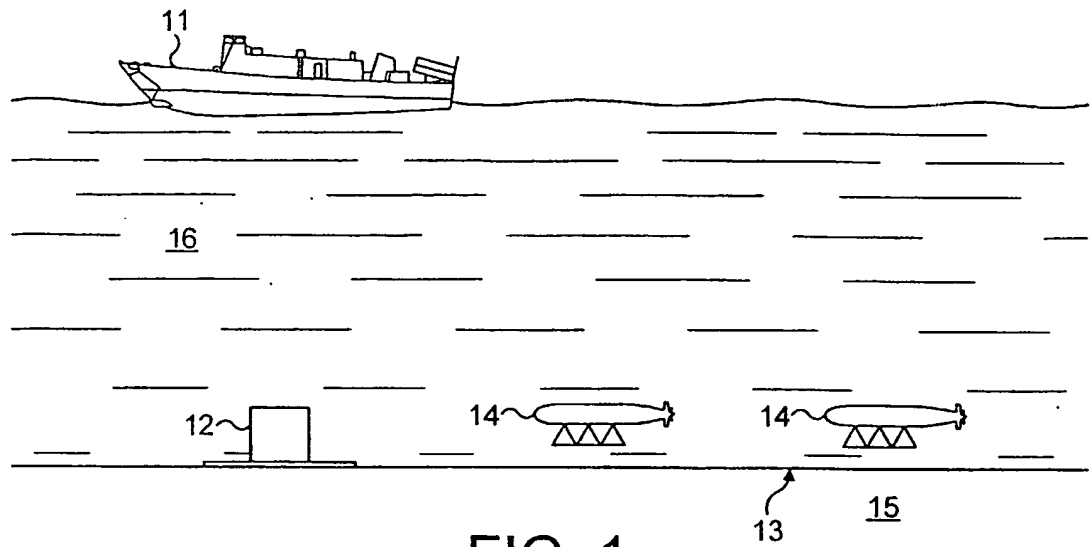
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31. Apparatus as claimed in any of Claims 21 to 30, in which the detecting apparatus comprises a plurality of monitoring devices (22) mounted on a plurality of cables, the monitoring devices on each cable being spaced from each other by a distance which is less than the wavelength of the transmitted seismic event.

25

32. A method of producing a seismic survey report of a region, which comprises: carrying out a method as claimed in any of Claims 1 to 20; deriving

from the analysing step, representations of subsurface layers; and assembling the representatives as a depiction of the geological structure of the region.



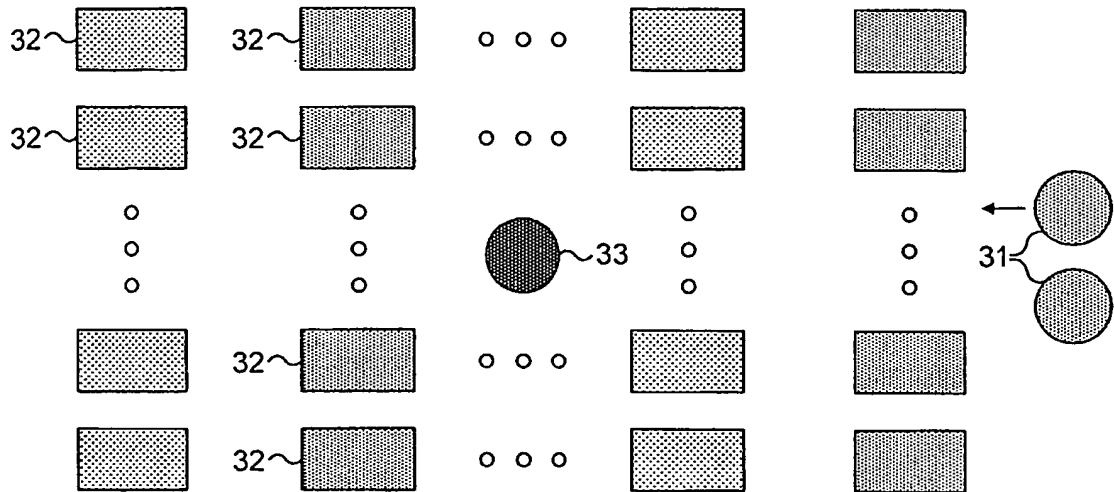


FIG. 3

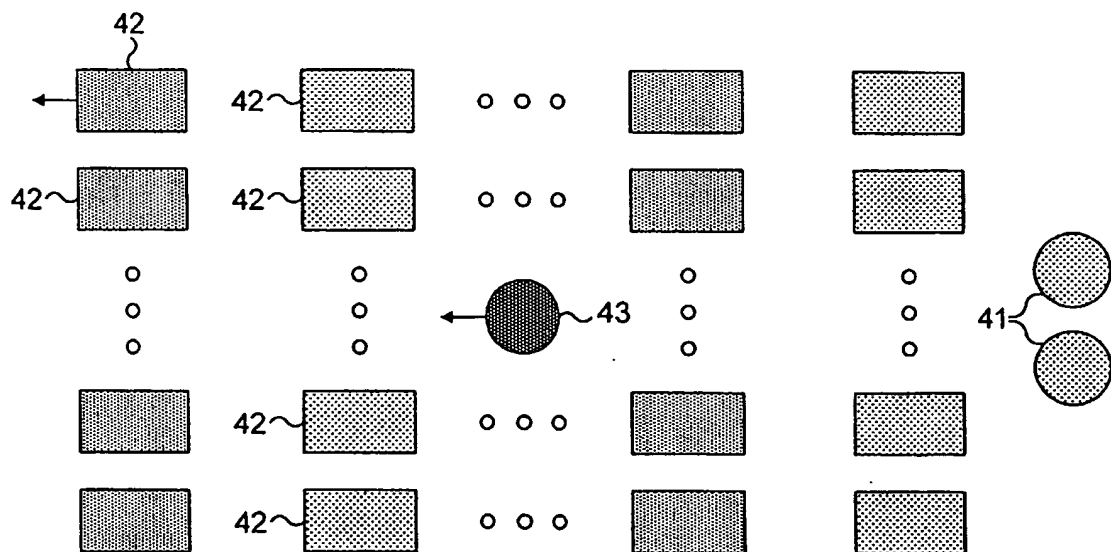


FIG. 4

INTERNATIONAL SEARCH REPORT

Int: onal Application No
PCT/GB 03/02823

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G01V1/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 134 966 A (DONSKOY DIMITRI M ET AL) 24 October 2000 (2000-10-24) column 3, line 8 - line 11 column 3, line 16,17 column 3, line 19,20 column 4, line 23 - line 25 column 4, line 33 - line 36 column 4, line 44 - line 50 column 4, line 53,54 column 5, line 53 - column 6, line 7 column 6, line 8,9 column 6, line 10 - line 26 figures 1,2	1-3,5,7, 8,11,13, 14, 16-19, 21-24, 27,28, 30,32
Y	-/-	6,9,25,

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Inte Application No
PCT/GB 03/02823

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>US 5 070 483 A (BERNI ALBERT J ET AL) 3 December 1991 (1991-12-03)</p> <p>column 5, line 21 - line 38 column 6, line 23 - line 30 column 7, line 56 - line 68 column 13, line 5 - line 10 column 21, line 5 - line 9 figures 3-5</p>	<p>26</p> <p>1-4,7,8, 13,14, 18,19, 21-23, 28,32</p>
X	<p>BERNI A J: "REMOTE SENSING OF SEISMIC VIBRATIONS BY LASER DOPPLER INTERFEROMETRY" GEOPHYSICS, SOCIETY OF EXPLORATION GEOPHYSICISTS, TULSA, US, vol. 59, no. 12, 1 December 1994 (1994-12-01), pages 1856-1867, XP000486460 ISSN: 0016-8033 page 1857, column 2 page 1858, column 1 page 1859, column 1 page 1862, column 2 page 1863, column 1 page 1866 -page 1867</p>	<p>1-5,7,8, 16, 21-23,32</p>
X	<p>GB 2 347 744 A (MARCONI ELECTRONIC SYST LTD) 13 September 2000 (2000-09-13)</p> <p>page 2, line 4 - line 14 page 3, line 20 -page 4, line 1 page 4, line 10 -page 5, line 12 page 7, line 21 -page 8, line 15 figure 1</p>	<p>1-3,5,7, 8,21,22, 24,32</p>
X	<p>DE 40 04 228 A (MANTEL JUVAL) 14 August 1991 (1991-08-14)</p> <p>column 1, line 31 - line 48 claim 1; figure 1</p>	<p>1-3,8, 11,12, 21-23, 27,32</p>
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Int'l Application No
PCT/GB 03/02823

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Information on patent family members

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